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ABSTRACT

Traditionally, disadvantaged groups, such as women and minorities, have not excelled in science and math. Often the lack of literacy and achievement in these subjects is due to the following factors: (1) cognitive differences between how the information is presented and how the students process it; (2) lack of familiarity, because of cultural differences with the context in which the material is taught; (3) family stress due to poverty and/or unemployment; (4) racial and cultural biases that may lead teachers and parents to believe that minorities and women cannot get jobs in technology or aren't suited for them, and therefore shouldn't waste effort learning subjects that will be of no career use; (5) the perception that physically disabled students cannot function safely in a technological environment; and (6) tracking that steers certain groups away from academic or technical courses. Recently a range of successful educational policies, programs, and methods have been identified to help these students. They are the following: (1) high quality programs with longevity and continuity; (2) high quality diverse staff who are role models for the participants; (3) recontextualization, which allows students to understand the material in the context of their own lives; (4) cultural and language sensitivity; (5) anxiety-reducing strategies; (6) improved programming; and (7) cooperative, heterogeneous grouping of students. Out-of-school programs and parental help are also effective in helping disadvantaged students. (VM)

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TEACHING SCIENCE AND MATHEMATICS TO AT RISK STUDENTS

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This digest was based in large part on research by Michael Cole and Peg Griffin of the Laboratory of Comparative Cognition that is presented in *Contextual Factors in Education: Improving Science and Mathematics Education for Minorities and Women*. This publication, published by the Wisconsin Center for Education Research, is available from the ERIC Clearinghouse on Urban Education for $2.00.

TEACHING SCIENCE AND MATHEMATICS TO AT RISK STUDENTS

Increasingly, applicants for the best employment opportunities will need a good grasp of science, mathematics, and computer technology. However, minorities, women, and other disadvantaged groups have not excelled in these areas. Why this is so, and what can be done to increase the scientific and mathematics literacy and achievement of these groups, are important educational concerns now.

Successful attempts to reverse this situation have been made recently, and as a result, a range of educational policies, programs, and methods to teach science and mathematics effectively have been identified and are now in use around the country.

Why Some Students Have Achievement Problems

Cognitive Differences. How individual students process the information they receive and approach problem solving vary greatly. Research has shown that within certain groups of students (i.e., minorities and women) most learn in a similar way, but in a way different from that defined by educators as the norm (i.e., the way white males learn). Because it is only this "normal" way of learning that has informed curriculum development, large numbers of students, and possibly the majority of some student groups, have failed to master science and mathematics coursework.

Family Stress. Students whose family life is in turmoil suffer the effects of this stress in several ways. First, parents under presure, even if it has nothing to do with childrearing, are severely hampered in their ability to help their children with schoolwork. Second, students themselves internalize family stress, and as it lowers their self-esteem, their ability to learn in school is inhibited.[1] The prime sources of family stress for many children at academic risk are poverty and unemployment, and the other social problems they engender.

Racial and Cultural Bias. The belief that certain students cannot excel at science and mathematics can easily become a self-fulfilling prophesy. Racial minorities have long been subject to this bias at school, where teachers treat them differently from white students by encouraging them to take less challenging, nonacademic courses. Teachers may believe that, given a history of low minority student achievement in science and mathematics, and possibly employment discrimination, it is better to prepare minority students for the jobs that will probably be available to them than to prepare them for other jobs usually held by white men. The lack of minority role models in technical fields suggests to teachers that their beliefs are valid, and suggests to students that they have little if any chance of succeeding when no other minority person has done so in the past. In addition, some minority students may be further hampered by their parents' diminished ambition for them, the result of their own lack of success in the world of higher education and employment.

Students whose first language is not English, or is a nonstandard English dialect, may have difficulty in understanding not only the words used to teach but also the cultural context of the learning material. Bilingual curriculum has, for the most part, been limited to the most basic subjects, so students have not even been given the opportunity to learn higher level science and mathematics in the language most familiar to them. Several

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studies have demonstrated that bilinguals have more difficulty than monolinguals in solving mathematics problems requiring semantic processing.[2] Other cultural differences between the way students are expected to behave at home and at school may inhibit their learning ability. For example, as shown in a 1971 study by Phillips (cited in Cole & Griffin[3]), Native American children at home are expected to be silent before a powerful adult and they are never singled out for praise or censure. At school, where students are expected to respond to their teacher's individual attention, these children are not comfortable participating in such interaction and find learning more difficult.

It has been a longstanding belief that female students cannot grasp higher level science and mathematics, and they have been encouraged not to take such courses. If they do take them, they are frequently ignored; teacher attention is concentrated on the male students who are assumed more likely to pursue careers in these fields.[4] A lack of women role models has also discouraged female students from pursuing science or mathematics careers,[5] as has the idea that women professionals in these fields are not as "feminine" as, say, women teachers or social workers. Here, as in minority families, parents' negative or outdated attitudes can suppress any ambitions for a career in technolgy that girls may have. According to a 1984 study by Chipman and Thomas (cited in Cole & Griffin[6]), by the time they reach high school most female students have already lost their interest in mathematics and science as a result of social pressure and an earlier lack of achievement in these areas.

Disability. Though scientific and technological literacy is particularly important for improving the quality of life of the handicapped, their chances of achievement in these areas are limited. Frequently they are "tracked" out of courses because of a misconception that they cannot function safely in a laboratory or could never work in a science setting.[7]

Tracking. The bias experienced by groups of students is not only the result of individual teachers' or parents conduct. Bias has been institutionalized in the school through tracking.[8] Just as minorities may be steered away from an academic curriculum and girls from technological courses, students who exhibit any kind of learning difficulty (the result, for example, of the above-discussed family stress) may be counselled to take less challenging classes instead of encouraged to work harder to master the more difficult ones. Such tracking can begin in the early grades, with the unfortunate result that students do not get the educational building blocks they need for more advanced learning later in their school careers.

How to Promote Achievement in School

Many components of programs that successfully teach mathematics and science to students have now been identified. While some of these are also aspects of the more general effective school principles, others uniquely respond to the needs of minorities and women.

High Quality and Long-Term Programs. Successful special programs start early and continue throughout the schooling of targeted groups.[9] It is important for students to be taught from the start the personal importance of learning science and mathematics. Moreover, the emphasis of science and mathematics curricula should be on enrichment, rather than on remediation, and should allow students the opportunity for hands-on experience. Early introduction to computers and ongoing hands-on experience have been identified as essential to later computer literacy in women, for example.[10] Programs should be enhanced through enlistment of universities, businesses, and the community in cooperative efforts.

Frequent evaluation of programs also increases effectiveness, for changes can be made along the way to capitalize on the most effective aspects of the program and to delete from it aspects which do not promote achievement. Finally, a diversified funding base helps ensure program longevity and continuity because, if one source fails to renew support, others can help carry the project while additional funds are sought.[11]

High Quality and Diverse Staff. Essential to an effective program are a strong principal and director, and competent teachers who all believe in students' ability to learn and who are committed to removing educational inequities related to sex, race, ethnic background, and disability. Staff at all levels need to be recruited from the target populations. Further, they should strive to introduce students to other role models of both sexes and with backgrounds similar to theirs.[12]

Recontextualization. For students to learn it is important for them to both understand the material presented, and relate it to their own lives.[13] To accomplish the former, the curriculum must be structured to take into account students' cognitive differences—that is, to create learning tasks that can be mastered through use of students' innate ways of understanding information.

Learning is also easier when presented in the context of students' own lives. This can be done by embedding the information to be taught and the problems to be solved in a context the students are familiar with. Once students realize how they can make immediate and practical use of what they are learning their attention will increase and, therefore, so will their comprehension and retention. Making personal connections requires that the curriculum take account of students' cultural and ethnic diversity, and that teachers have knowledge of and respect for it. For example, a classroom guide presented at the Michigan Annual Hispanic Education Conference is designed to interest Hispanics and American Indians in the sciences by focusing on significant non-Western contributions to civilization.[14]

Relating science and mathematics learning to future careers, and demonstrating the growing importance of mastery in these areas to nearly all employment opportunities, is another important way of demonstrating the relevancy of these subjects. In the past, the connections between early course decisions and later career choices have not been clearly shown to students. The value of good science and mathematics education is not limited to students who aspire to white collar careers; even those students planning to enter vocational programs—and female students are now being especially encouraged to consider these nontraditional alternatives—will need a good foundation in mathematics.[15]

Cultural and Language Sensitivity. As indicated above, teachers must understand and take into account the cultural factors that inform students' ability to learn. For example, children used to assuming responsibilities and functioning autonomously at home will learn better in more independent situations. Similarly, students used to using a nonstandard method of communicating should be allowed to learn and express themselves in that way.[16] Of course, teachers must be sure that students fully comprehend their own speech, and

must be willing to "translate" if necessary.

Bilingual classes in advanced science and mathematics can be crucial to student's mastery of these subjects. Frequently students who appear to understand English cannot comprehend it in more advanced or technological classes, so their failure in these classes may be the result of a language gap rather than a cognitive deficiency.

Anxiety-Reducing Strategies. Traditionally, the teaching of mathematics, with its focus on arriving at a correct answer before one's fellow students do, creates a competitive classroom atmosphere that provokes anxiety in some students. Northeast EQUALS, a project that conducts mathematics workshops, uses a cooperative approach that eliminates the stress of competition and the value conflict experienced by females and some minority group students who value cooperative social interaction. Instilling in students the belief that they can succeed also helps reduce anxiety.[17] The parent organization of Northeast EQUALS, operated by the Lawrence Hall of Science at the University of California, Berkeley, offers a wide range of materials for teachers and students that stress the potential for all students to master science, engineering, math, and computer technology courses.[18] In addition, the Teacher Education and Mathematics project has developed Teacher Education and Mathematics Education modules that acquaint elementary school teachers with possible sex bias problems that might occur in the teaching of math, and offers curriculum guides for overcoming these problems particularly and reducing mathematics anxiety generally.[19]

Improved Programming. Many studies have demonstrated that student learning—no matter what the subject—increases as class size decreases. Smaller class size means more interaction between students and teacher. It has also been well documented that students learn better when in closer contact with teachers—or paraprofessionals, parent aides, student tutors, and others present in the classroom for the purpose of working with students—than when doing "seatwork."[20]

Increased time on task is another way to improve learning. More time for learning can be carved out of the school day by limiting teachers' administrative tasks and monitoring students' activities to ensure that they have the time that they need for each learning task. Developing learning activities that take less time to master is also a way of freeing time in the day for additional learning tasks; recontextualization, described above, often results in more rapid learning, thus allowing more material to be covered in a day.

Cooperative Student Groupings. Though most science teachers rely on a textbook for their course outlines, and use the lecture method of teaching, Kyle (cited in Cole & Griffin[21]) has shown that a hands on, inquiry-oriented science curriculum is far more effective. Such a curriculum can best be used when students are divided into small mixed ability cooperative groups, with each functioning independently to accomplish learning tasks, solve problems, and achieve a continually evolving set of goals. Since teachers necessarily can offer only limited time to each group, the tasks assigned and resources provided must lend themselves to independent learning with only intermittent teacher input. It is also important for the groups to be truly heterogeneous; groups comprised of primarily historically poor learners are unlikely to be effective. To prevent group domination by higher status students, teachers must intervene to ensure that all students have an opportunity to shine within the group at one time or another. This can be accomplished by giving lower status students individual training in areas in which they would not ordinarily be expected to excel and then letting those students train the others in the group. The principle of heterogeneous groups applies to computer education where students are frequently paired. Cross-sex and mixed ability pairings have resulted in more effective learning than have random pairings.[22]

How To Increase Learning Through Out-of-School Programs

To provide at risk students with effective science and math education not provided in school, or to supplement school programs, both schools and organizations have begun to offer independent programs. Increasingly, museums, zoos, planetariums, aquariums, and other institutions are providing students with educational enrichment; this may well be the beginning of a trend for schools to be just one source among many of students' educational experiences.[23]

Some organizations have programs for one specific group of at risk students. For example, programs for female students include Operation SMART (Science, Math and Relevant Technology) of the Girls Clubs of America, and the Women in Science project of the American Association for the Advancement of Science.[24] There are also special programs for minority students, including the Education Initiative of the National Urban League, which is comprised of individual enrichment programs in science and math, as well as other curriculum areas, and is administered by local affiliates;[25] and Project MICRO (Minority Computer Resources Opportunity) of the Southern Coalition for Educational Equity, which introduces computer uses to minority students, their parents, and their teachers.[26]

How Parents Can Help Their Children

Parents must offer their male and female children equal encouragement and equal opportunities to participate in science and mathematics experiences. In fact, providing children with hands on experience—as simple as involving them in the math required of household budgeting—demonstrates its relevancy. Minority and poor parents must convey to their children the real possibility of a career in science or mathematics regardless of whether there are relevant role models in the family, the neighborhood, or the workplace.

Working with other parents to improve the science and mathematics education offered in school; investigating locally available resources, such as computers in the local library; and finding out about out-of-school programs and helping to enroll their children in them are also supportive actions for parents to take.

Finally, parents can encourage learning by participating in joint learning experiences. For example, the Center for the Development of Non-Formal Education in Austin, TX, offers parents and their children bilingual computer education. In Irvine, CA, there is a cable television call-in program after school that answers students' academic questions, and in Los Angeles the public television station airs a Homework Hotline;[27] parents can, optimally watch and discuss these programs with their children, or at least make viewing them part of their children's nightly homework.

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